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A STUDY OF POLLUTION LOAD CAPACITY OF THE INDUSTRIAL SECTOR IN CIBABAT RIVER IN THE WATERSHED OF CITARUM RIVER

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ABSTRACT

The Sub Watershed of Cibabat is one of the rivers included in the Upstream Citarum River, in Cimahi City. This industrial sector which consists of 36 different industries is among the highest contributors of pollution load. **Aim:** This study analyzed the pollutant loads entering the Cibabat River in existing conditions and projections from the industrial sector. **Methodology and Results:** The pollutant loads, emitted from the industrial sector was used to calculate the discharged data, concentration, number of employees and products, as well as emission factors (EF). In 2018, the industrial sector pollution load was 3,518.82 kg/day TSS, 8,231.83 kg/day BOD and 14,467.68 kg/day COD. However, it increased to 3,885.06 kg/day TSS, 9,088.61 kg/day BOD and 15,973.48 kg/day COD during this project year. **Conclusion, significance and impact study:** The pollution loads on Cibabat River emitted from the industrial sector, which increases yearly by 2% was be reduced by developing wastewater treatment communal for industries.

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KEYWORDS

- Cibabat sub-watershed
- Emission factors (EF)
- Industrial sector
- The pollution loads

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1. INTRODUCTION

Water is a natural resource needed for humans and other living things, for this reason, it is necessary to maintain the quality of water so that water can provide its function for the life of living things (Effendi, 2003; Suharto *et.al,* 2019). According to Law Number 32 of 2009 concerning Environmental Protection and Management, Environmental Capability is the ability of the environment to absorb substances, energy and/or other components that enter or are incorporated into it. As time develops, Cimahi City has increased the population and industrial growth that is increasingly rapid. The existence of industry and population growth around the Sub Watershed of Cibabat will affect the water quality of the Cibabat River, according to the Environment Agency (EA) of Cimahi City, Cibabat River contributes 68.89 percent COD (chemical oxygen demand) from domestic activities and 30.97 percent from domestic activities, BOD (biological oxygen demand) of 69.98 percent of industrial activities and 30 percent of domestic activities. A total of 36 industries with different types of industries are in the Sub Watershed of Cibabat in Cimahi City (Environment Agency of Cimahi City, 2018). Industries are located in the middle of the 11 industries and 25 industries downstream.

Based on these conditions, the need for a study of pollution load capacity that can be accepted by the Sub Watershed of Cibabat is to determine the appropriate control program in the management of the Sub Watershed of Cibabat. The purpose of this study was to contribute the control of water pollution in the Cibabat River through a study of pollution load capacity in the Sub Watershed of Cibabat, especially in the industrial sector.

2. RESEARCH METHODOLOGY

2.1 Research Location

Cibabat River was located in Cimahi City, West Java, the location of the Cibabat River point sampling determined by the Environment Agency of Cimahi City was as follows:

- Upstream Cibabat River: 06°52'28.9" S; 107°33'41.3" E
- Middle Cibabat River: 06°53'21.9" S; 107°33'24.3" E
- Downstream Cibabat River: 06°54'00.8" S; 107°32'54.6" E

There were 36 industries in the Sub Watershed of Cibabat with different types of activities,

spread in Sub-district of Cimahi Tengah and Sub-district of Cimahi Selatan with different industrial activities, so that each industry used different methods based on the data information because not all industries had monitoring data. The list of industries that are around the Cibabat River by each industry method show in Table 1.

Table 1 List of Sub Watershed of Cibabat Industries

No	Location	Name of Company	Types of Industry	Method
1	Sub-district of Cimahi Tengah (Upstream)	Bahtera Laju sentosa	Various Industry	-
2		PT Afiat	Various Industry	-
3		RSU Kasih Bunda	Hospital	EF x Σ Employee
4		PT Perseroan Dagang dan Industri Farmasi Afiat	Pharmacy	-
5		PT Trisula Tekstil Industri	Textiles	-
6		PT Bina Usaha Cipta Prima	Textiles	Qm x C
7		PT Sinar Sangjaya Mulia	Various Industry	EF x Σ Product
8		Nam Nam Fashion Industries	Various Industry	-
9		PT Bratatex	Textiles	EF x Σ Employee
10		Benang Warna Ind	Textiles	EF x Σ Employee
11		Focus Gaya Prima	Textiles	-
12	Sub-district of Cimahi Selatan (Downstream)	PT Sinar Continental	Textiles	Qm x C
13		CV Suritex	Textiles	EF x Σ Employee
14		PT Indowira Putra	Paint Industry	EF x Σ Employee
15		PT Garuda Mas Semesta	Textiles	Qm x C
16		PT Theodore Garmindo	Various Industry	EF x Σ Employee
17		PT Rajawali Hiyoto	Paint Industry	Qm x C
18		Hanna Collection	Textiles	-
19		CV Priangan	Various Industry	-
20		Anugrah Sinar Abadi	Textiles	-
21		Berdirikari Metal Engineering	Various Industry	-
22		PT Citra Bandung Laksana	Various Industry	-
23		PT Dialogue Garmindo Utama	Various Industry	-
24		E L G A	Metal Industry	-
25		PT Sanlit Inti Plastik	Various Industry	-
26		PT Ayoe Indotama Tekstil	Textiles	Qm x C
27		PT Laju Makmur Sentosa	Various Industry	Qm x C
28		PT Tridharma Megamitra	Various Industry	-
29		PT Sinar Pangjaya Mulia Tekstil Industri (Cabang)	Textiles	-
30		PT Aswindo Jaya Santosa	Textiles	Qm x C
31		PT Mulus Garuda Jaya	Textiles	-
32		PT Nam Nam Fashion Industry	Textiles	-
33		PT Tegar Prima Nusantara	Various Industry	EF x Σ Product
34		Indah Jaya	Textiles	-
35		PT Central Georgette Nusantara	Textiles	EF x Σ Employee
36		PT Elizabeth Hanjaya	Various Industry	EF x Σ Employee

Source: Environment Agency of Cimahi City, 2018

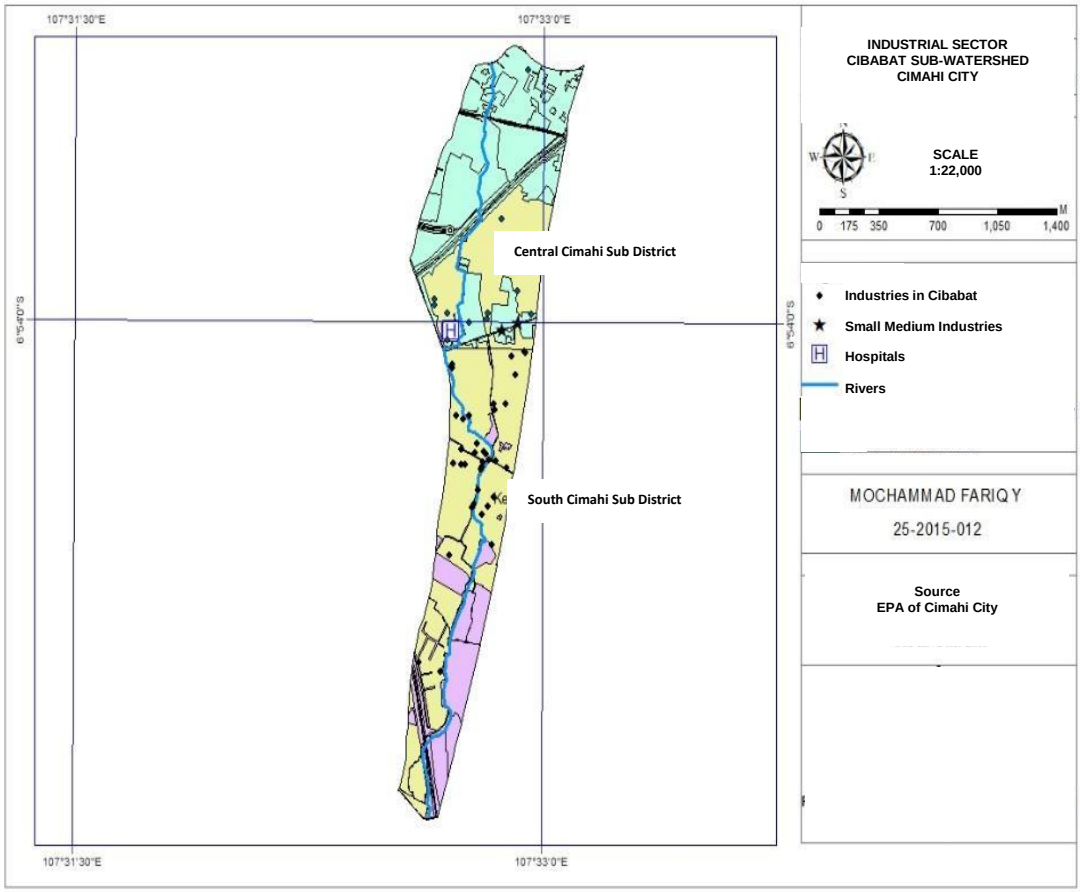

Figure 1 Distribution of the industrial sector of sub watershed of Cibabat

2.2 Calculation of Industrial Sector Pollutant Load

The calculation of existing pollutant load capacity is the result of the calculation of the difference in pollutant load at maximum conditions with the value of pollutant load in the actual condition. A river can be said to exceed its load capacity when the resulting value is negative (Minister of the Environment, 2010).

The calculation of industrial sector pollutant load was carried out by using an approach, in which this approach was carried out due to the limitations and availability of information in each industry, a hierarchical approach carried out by SEMAC JICA in 2009, namely:

1) Using monitoring results data in the form of discharge and concentration of industrial wastewater (1st hierarchy). Existing pollutant loads in the industrial sector can be calculated by the equation (Iskandar, 2007):

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$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_x = Q(m^3/sec)\ X\ Cx\ (mg/l) \quad (1)$$

2) The second hierarchy is used if there is a concentration of wastewater produced by industry and the discharge of its wastewater is assumed to be the maximum discharge in a similar industry. Existing pollutant loads in the industrial sector can be calculated by the equation (Iskandar, 2007):

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_x = Q(m^3/sec)\ X\ Cx\ (mg/l) \quad (2)$$

3) The third hierarchy uses data on the number of workers/employees in industry and pollution load unit or emission factor (EF). The value of pollution load unit or emission factor (EF) from BOD parameter shows in Table 2.

Table 2 BOD Emission Factors for Industrial Waste

Number	Industrial Sector	Emission Factors (gr/day/employee)
1	Coloring/Dyeing	79.1
2	Food	37.9
3	Metal	10.3
4	Paper	17.9
5	Polyester Fiber	47.1
6	Textiles	291.2
7	Laundry	96.4
8	Machine	4.7
9	Plastic Goods	57.3
10	Car/motorcycle parts	13.5
11	Ceramics and tiles	2
12	Tannery	144.4
13	Soap and detergent	50.4
14	Chemical/paint	1898.20
15	Metal Goods	0.2
16	Printing	0.6
17	Glass	0.3
18	Hospital	123
19	Hotel	55
20	Restaurant	17

Source: Iskandar, 2007

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The contents of research methodology were the methods used to obtain the objectives of the research/study in this scientific paper. If the scientific work was in the form of planning or design, then this chapter would be entitled Fundamentals of Planning. Use reliable methods and appropriate planning basis.

COD concentrations were calculated by using the BOD/COD ratio approach. BOD/COD ratio based on types of industrial waste shows in Table 3.

Table 3 BOD/COD comparison ratio based on industrial waste

Number	Industrial waste	Ration BOD/COD
1	Tannery	79.1
2	Polyester Fiber	37.9
3	Textile Dyes	10.3
4	Chemical/Paint	17.9
5	Pharmacy	47.1
6	Tobacco	291.2
7	Paper	96.4
8	Protein Process (Food)	4.7
9	Vegetable oil	57.3
10	Hospital	13.5
11	Metal industry	2

Source: Eckenfelder, 2000

The existing pollutant load of BOD and COD parameters of the industrial sector can be calculated by the equation (Iskandar, 2007):

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = \Sigma \text{Employee(person)} X\ EF(\frac{\frac{gr}{person}}{day}) \quad (3)$$

Then:

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{COD} = \frac{Pollutan\ Load\ BOD}{BOD/COD\ ratio} \quad (4)$$

4) The fourth hierarchy is used based on the total of production from an industry (World Health Organization, 1982). The calculation of potential pollutant load can be done by multiplying the total of production with emission factors. The emission factor used for fourth hierarchy uses publications used by the 1982 world health organization

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = \Sigma \text{product x Emission Factor} \quad (5)$$

The projection of the industrial sector pollutant load was based on the industrial sector pollutant data in 2018. The calculation of the projected industrial sector pollutant load was carried out from 2019 to 2023 (5 years).

The projection of industrial sector was carried out with an approach by following research conducted by Bukit and Yusuf (2002) who examined trends in industrial growth in the Upstream Citarum River to determine industrial waste management strategies. The study explained that 2010-2020 had an increase in the average of the industrial sector by 2% per year. Based on this research, the calculation of the projected industrial sector pollutant load in the Sub Watershed of Cibabat by using a percentage increase in the industrial sector was 2% in 2019 to 2023.

3. RESULTS AND DISCUSSION

3.1 Current Pollutant Loads

The industrial sector pollutant load in the Sub Watershed of Cibabat was located in the area of Cimahi Tengah (upstream) Sub-district and Cimahi Selatan (downstream) Sub-district, 36 industries scattered in the Sub Watershed of Cibabat with different types of activities.

The number of industries in the Sub Watershed of Cibabat was 36 industries, but 19 industries were not counted due to data limitations so that the total industry of the Sub Watershed of Cibabat was 17 industries. The calculation of industrial sector pollutant load by each method can be seen as follows:

1) Potential Pollutant Loads Based on Existing Discharge and Concentration Data.

   The existing discharge and concentration data is generated from each industry. Table 4 is a recapitulation calculation of industrial sector pollutant load based on existing discharge and existing concentration data, the following is an example of the calculation of potential pollutant load with BOD parameters at PT Ayoe Indotama Tekstil.

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = Q\ (m^3/\text{sec})\ x\ C\ (mg/l)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} =$$

$$5997 m^3/sec\ x\ 21.01 mg/l\ x\ 10^{-6}(kg/mg)\ x\ 10^3(l/m^3)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 126\ kg/day$$

Table 4 Potential pollutant loads of industrial sector with discharge and concentration data in 2018

Location	Name of company	Types of industry	Discharge (m3/day)	Pollution Concentration (mg/l)			Potential Pollutant Loads (kg/day)		
				TSS	BOD	COD	TSS	BOD	COD
Sub-district of Cimahi Selatan (Down stream)	PT Rajawali Hiyoto	Paint Industry	256.17	27.63	38.48	-	7.08	9.86	18.6
	PT Ayoe Indotama Tekstil	Textiles	5997	35.1	21.01	42.66	210.49	126	255.83
	PT Laju Makmur Sentosa	Various Industries	1.38	6.4	51.2	90.9	0.01	0.07	0.13
Total Potential Pollutant Loads of Industrial Sector in 2018 (kg/day)							271.58	135.93	274.56

2) Potential Pollutant Loads Based on Existing Wastewater Concentration and Assumptions on Discharge.

This calculation is carried out by using the concentration of existing wastewater and the assumption of discharge based on maximum discharge in similar industries. Table 5 is a recapitulation of the potential pollutant load in the industrial sector with assumption discharge data and maximum discharge in similar industries. The following is an example of the calculation of the potential pollutant load of the industrial sector with BOD parameters at PT Bina Usaha Cipta Prima using the maximum discharge of PT Ayoe Indotama Tekstil (5,997 m^3/day):

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = Q\ (m^3/\text{sec})\ x\ C\ (mg/l)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 5997 m^3/\text{sec}\ x\ 4.94\ mg/l\ x\ 10^{-6}(kg/mg)\ x\ 10^3(l/m^3)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 29.63\ kg/day$$

Table 5 Potential pollutant loads of industrial sector based on discharge assumptions and maximum discharge in similar industries

Location	Name of company	Types of industry	Discharge (m^3/day)	Pollution Concentration (mg/l)			Potential Pollutant Loads (kg/day)		
				TSS	BOD	COD	TSS	BOD	COD
Sub-district of Cimahi Tengah (Upstream)	PT Bina Usaha Cipta Prima	Textiles	5,997 (PT Ayoe Indotama Tekstil)	1.08	4.94	9.67	6.48	29.63	57.99
Sub-district of Cimahi Selatan (Down stream)	PT Sinar Continental	Textiles	5,997 (PT Ayoe Indotama Tekstil)	60	164	235.5	359.8	983.5	1,412.3
	PT Garuda Mas Semesta	Textiles	5,997 (PT Ayoe Indotama Tekstil)	23.4	10.2	58.02	140.3	61.05	347.95
	PT Aswindo Jaya Santosa	Textiles	5,997 (PT Ayoe Indotama Tekstil)	17.1	16.4	30.92	102.6	98.35	185.43
Total Potential Pollutant Loads of Industrial Sector in 2018 (kg/day)							609.18	1,172.5	2,003.66

3) Potential Pollutant Loads Based on Data on Number of Workers and Emission Factors.

The calculation of industrial sector pollutant load can be calculated by using data on the number of workers and emission factors with BOD parameters (Table 2) so that it will not produce pollutant load values with other parameters. The calculation of industrial sector pollutant load with COD parameters is obtained by using a BOD/COD ratio comparison approach based on industry type (Table 3). The following is an example of the calculation of industrial sector pollutant load based on data on the number of workers and emission factors in PT Benang Warna Ind (textile industry) with BOD parameters:

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = \Sigma \text{Employee(person)} X\ EF(gr/person/day)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 682 \text{people}\ X \frac{291.2 \frac{gr}{person}}{day} \text{x}\ 10(\text{gr/kg})$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 198.6\ kg/day$$

Then:

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{COD} = \frac{Pollution\ Load\ BOD}{Ratio\ BOD/COD}$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = \frac{198.6\ kg/day}{0.53} = 374.71\ kg/day$$

Table 6 Potential pollutant loads of industrial sector based on number of employees and emission factor

Location	Name of company	Types of industry	Total of employee (person)	Emission factor (gr/person/day)		Potential Pollutant Loads (kg/day)	
				BOD	COD	BOD	COD
Sub-district of Cimahi Tengah (Upstream)	Kasih Bunda Public Hospital	Hospital	274	123	-	33.702	51.85
	PT Brataex	Textiles	700	291.2	-	203.84	384.6
	Benang Warna Ind	Textiles	682	291.2	-	198.6	374.71
Sub-district of Cimahi Selatan (Downstream)	CV Suritex	Textiles	703	291.2	-	204.71	386.25
	PT Indowira Putra	Paint Industry	200	1898.2	-	379.64	677.93
	PT Theodore Garmindo	Various Industries	768	291.2	-	223.64	421.97
	PT Central Georgette Nusantara	Textiles	700	291.2	-	203.84	384.6
	PT Elizabeth Hanjaya	Various Industries	800	291.2	-	232.96	439.55
Total Potential Pollutant Loads of Industrial Sector in 2018 (kg/day)						1680.932	3121.46

Source: Analysis Results, 2019

4) Potential Pollutant Loads Based on the Total of Production

The calculation of potential pollutant load can be done by multiplying the total of production with emission factors. The emission factors are used by using publications used by the world health organization (1982). The following is an example of calculation of potential pollutant loads based on the total production data of PT Sinar Pangjaya Mulia with BOD parameters:

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = \Sigma \text{Production X Emission Factor}$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 10000\left(\frac{\text{kg}}{\text{day}}\right) \text{X } 185\ (\frac{\text{kg}}{\text{year}}) \text{X } (\frac{\text{year}}{365\text{day}})$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 5068.49\frac{kg}{day}$$

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Table 7 Potential pollutant loads of industrial sector based on the total production

Location	Name of company	Types of industry	Total of Production (kg/day)	Emission factor (kg/year)			Potential Pollutant Loads (kg/day)		
				TSS	BOD	COD	TSS	BOD	COD
Sub-district of Cimahi Tengah (Upstream)	PT Sinar Pangjaya Mulia	Various Industries	10,000	95	185	320	2,602.74	5,068.49	8,767.12
Sub-district of Cimahi Selatan (Down stream)	PT Tegar Primma Nusantara	Various Industries	343.19	85	185	320	89.32	173.95	300.88
Total Potential Pollutant Loads of Industrial Sector in 2018 (kg/day)							2,692.06	5,242.44	9,068

Source: Analysis Results, 2019

After obtaining the potential pollutant load in each industry, Table 8 is a recapitulation of the potential pollutant load in the industrial sector in 2018 in the Sub Watershed of Cibabat.

Table 8 Potential pollutant loads of industrial sector based on the total production

Number	Location	Name of company	Potential pollutant loads kg/day)		
			TSS	BOD	COD
1	Sub-district of Cimahi Tengah (Upstream)	Kasih Bunda Public Hospital	-	33.702	51.85
2		PT Bina Usaha Cipta Prima	6.48	29.63	57.99
3		PT Sinar Pangjaya Mulia	2,602.74	5,068.49	8,767.12
4		PT Bratatex	-	203.84	384.6
5		Benang Warna Ind	-	198.6	374.41
Potential Pollutant Loads of Industrial Sector (Upstream)			2609.22	5,534.26	9,636.28
6	Sub-district of Cimahi Selatan (Downstream)	PT Sinar Continental	359.82	983.51	1,412.29
7		CV Suritex	-	204.71	386.25
8		PT Indowira Putra	-	379.64	677.93
9		PT Garuda Mas Semesta	140.33	61.05	347.95
10		PT Theodore Garmindo	-	223.64	421.97
11		PT Rajawali Hiyoto	7.08	9.86	18.6
12		PT Ayoe Indotama Tekstil	210.49	126	255.83
13		PT Laju Makmur Sentosa	0.01	0.07	0.13
14		PT Aswindo Jaya Santosa	102.55	98.35	185.43
15		PT Tegar Prima Nusantara	89.32	173.95	300.88
16		PT Central Georgette Nusantara	-	203.84	384.6
17		PT Elizabeth Hanjaya	-	232.96	439.55
Potential Pollutant Loads of Industrial Sector (Downstream)			909.6	2,697.58	4,831.41
Total Potential Pollutant Loads (kg/day)			3,518.82	8,231.84	14,467.7

Source: Analysis Results, 2019

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3.2 Potential Pollutant Loads Projection of Industrial Sector

The calculation of the potential pollutant loads projection of the industrial sector by multiplying the percentage increase in the industrial sector with the potential pollution load of the industrial sector in 2018. The potential pollutant loads projection of industrial sector starts from 2019-2023. The following is an example of the calculation of the potential pollutant loads projection of the industrial sector in 2023 with BOD parameters:

$$Pollution\ Load\ Industry_{2023}\ BOD = Pollution\ Load\ Industry_{2022} + (Pollution\ Load\ Industry\ Industry_{2022}\ x\ \%\ Increase)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 8910.4\frac{\text{kg}}{\text{day}} + (8910.4\frac{kg}{day}\ x\ 2\%)$$

$$Pottential\ Pollution\ Load\ of\ Industry\ parameter_{BOD} = 9088.61\ \text{kg/day}$$

Table 9 Potential pollutant loads projection of industrial sector in 2023 in Cibabat sub-watershed

Number	Location	Name of company	Potential pollutant loads (kg/day)		
			TSS	BOD	COD
1	Sub-district of Cimahi Tengah (Upstream)	Kasih Bunda Public Hospital	-	37.21	57.25
2		PT Bina Usaha Cipta Prima	7.15	32.71	64.03
3		PT Sinar Pangjaya Mulia	2,873.63	5,596.03	9,679.61
4		PT Bratatex	-	225.06	424.3
5		Benang Warna Ind	-	219.27	424.63
Potential Pollutant Loads of Industrial Sector (Upstream)			2,880.78	6,110.28	10,639.2
6	Sub-district of Cimahi Selatan (Downstream	PT Sinar Continental	397.27	1,085.87	1,559.29
7		CV Suritex	-	226.02	426.45
8		PT Indowira Putra	-	419.15	748.49
9		PT Garuda Mas Semesta	159.94	67.4	384.16
10		PT Theodore Garmindo	-	246.92	465.88
11		PT Rajawali Hiyoto	7.81	10.88	20.53
12		PT Ayoe Indotama Tekstil	232.4	139.11	282.46
13		PT Laju Makmur Sentosa	0.01	0.08	0.14
14		PT Aswindo Jaya Santosa	113.22	108.59	204.73
15		PT Tegar Prima Nusantara	98.62	192.05	332.19
16		PT Central Georgette Nusantara	-	225.06	424.63
17		PT Elizabeth Hanjaya	-	257.21	485.25
Potential Pollutant Loads of Industrial Sector (Downstream)			1,004.28	2,978.34	5,334.2
Total Potential Pollutant Loads (kg/day)			3,885.06	9,088.62	15,973.4

Source: Analysis Results, 2019

Based on the calculation results, the potential pollutant loads projection of industrial sector in 2023 with a BOD parameter of 9088.61 kg/day, the potential pollutant load is due to the industry in the Sub Watershed of Cibabat area dominated by the textile industry, textile wastewater generally has a high organic content (von Sperling, 2007).

Figure 2 is a graph of the potential increase in pollutant load in the Sub Watershed of Cibabat industry sector 2019-2023.

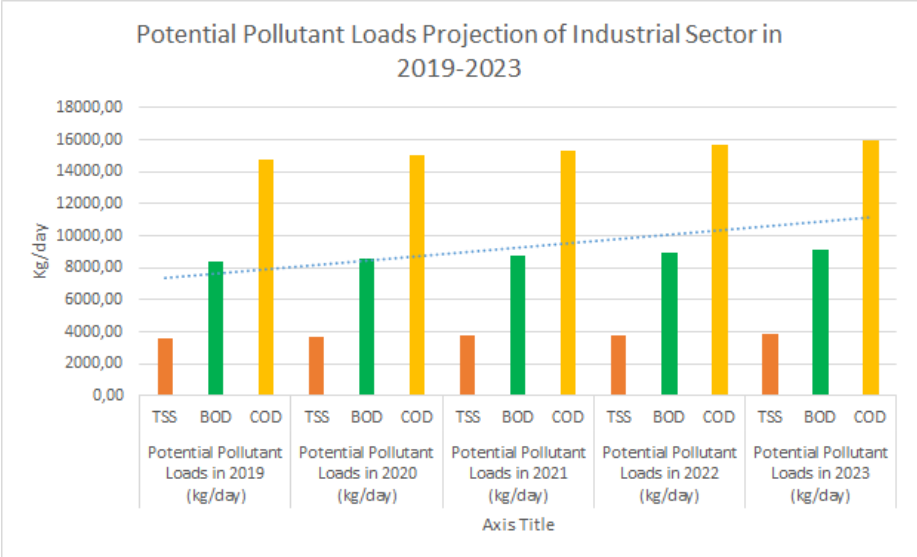

Figure 2 Graphic on increasing potential pollutant loads of industrial sector in Cibabat sub-watershed

The industrial sector pollutant loads in Sub Watershed of Cibabat have increased every year due to an increase in the industrial sector by 2% per year. This increase in organic parameters will cause oxygen dissolved in water to decrease, this is because organic parameters are food for microorganisms that will multiply rapidly and reduce dissolved oxygen in water.

4. CONCLUSION

Potential pollutant loads of industrial sector in Sub Watershed of Cibabat in 2018 with parameters TSS = 3,518.82 kg/day, BOD = 8,231.83 kg/day and COD = 14,467.68. Whereas in the projection year (2023) is 3,885.06 kg/day TSS, 9,088.61 kg/day BOD and 15,973.49 kg/day COD. The increase in the potential pollutant loads of industrial sector is due to an increase in the industrial sector by 2% per year.

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